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TO THE QUESTION OF IONIZED GAS DISTRIBUTION NEAR THE GALACTIC PLANE

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SUMMARY

This note gives account of some results of polarization measurements carried out with the view of ascertaining the character of the distribution of ionized interstellar gas. Referring to previous data on the variation of cosmic radioemission spectrum in the 1 ÷ 10 Mc frequency band, which led to assume that there is near the galactic plane an ionized gas forming a layer $\sim$ 300 nc thick, with concentration $N \sim 0.1\ cm^{-3}$ and temperature $T \sim 10^{4}\,°K$, the present authors question the conclusion of previous authors concerning its unambiguity, whereby radiowave absorption in that layer is cause of spectrum variation of low-frequency cosmic radio emission.

* * *

The assumption was expressed in the work [1] on the basis of spectrum variation of cosmic radio emission in the 1 ÷ 10 Mc frequency band that near the galactic plane there exists ionized gas with concentration $N \sim 0.1\,cm^{-3}$ and temperature $T \sim 10^{4}\,°K$; this layer has a half-thickness of $\sim$ 300 nc, and the absorption in this layer of radiowaves precisely leads to to the variation of the spectrum of low-frequency radio emission. However, this conclusion is not unambiguous, for the mean absorption factor of radiowaves is proportional to $\overline{N^2 T^{-3/2}}$, whereas the correlations $\overline{N^2} \sim (\overline{N})^2$ and $T \sim 10^{4}\,°K$ may well not be fulfilled. Moreover, one must bear in mind

* K VOPROSU O RASPREDELENII IONIZIROVANNOGO GAZA VBLIZI GALAKTICHESKOY PLOSKOSTI

the following two moments. First of all, absorption of cosmic radio emission may be to some extent linked with the H II region surrounding the solar system (the presence of such a region is assumed in the works [3, 4]. Secondly, if the metagalactic component prevails in the longwave cosmic radio emission [5], the variation of c.r.emission spectrum in low frequencies may be conditioned by radiowave absorption in the metagalactic medium [6]. Consequently, to ascertain the character of the distribution of ionized interstellar gas it is necessary to examine additional experimental data. Below we shall analyze some of the results of polarization measurements.

A review of the sky in polarization radiation of frequency $\nu = 408$ Mc has been made in a recently published work [7]. Attention is drawn in this review by several peculiarities as follows : 1)nearly 90 % of polarized radiation is concentrated in a band of 50° width passing by its middle part through the poles of the Galaxy [7]; the intensity of the polarized component is distributed in the band quite irregularly (spots); 2) with the removal from the center of the band by $\pm 15^{\circ}$ the intensity of the polarized component does not practically decrease, as an average; 3) in certain extended regions the electric vector is mostly directed along the band [7], and at the same time, the position angles' differences do not exceed, within the limits $\pm 15^{\circ}$ from the center, one radian as an average.

Such a distribution over the sky of polarized radiation must reflect the characteristic peculiarities of the structure of the galactic magnetic field, of the distribution of relativistic electrons, and of ionized interstellar gas. In order to obtain a representation of the distribution of the latter, we shall consider two simplest models of the Galaxy region, where the polarized radio emission originates. Assume that the polarized radiation emerges in a Galactic arm of radius R_p, on whose axis the solar system is located [7, 11]. We shall estimate the concentration of relativistic electrons and the magnetic field as constant in the arm. Let the magnetic field be parallel to the arm's axis, the direction of velocities of relativistic electrons being distributed isotropically. We shall assume in the first model that the ionized gas is distributed uniformly in the arm with radius $R_1 < R_p$.

In the second model we shall assume the gas to be concentrated in comparatively dense clouds.

Let us consider to begin with the first model. With the above made assumptions we may show that the degree of radiation polarization is

$$p=\frac{\gamma+1}{\gamma+7/3}\frac{R_i}{R_p}\sqrt{\frac{\sin^2(\psi\operatorname{ctg}\theta)}{(\psi\operatorname{ctg}\theta)^2}+\frac{R_p-R_i}{R_i}\frac{\sin(2\psi\operatorname{ctg}\theta)}{\psi\operatorname{ctg}\theta}+\left(\frac{R_p-R_i}{R_i}\right)^2}, \qquad (1)$$

where γ is the exponent in the energy spectrum of relativistic electrons, $\psi = 2.4\cdot 10^4\, NHR_i/\nu^2$ is a factor determining the value of the Faraday rotation of the polarization plane of cosmic radio emission in the gas arm; H is the intensity of the magnetic field in oersted (in the expression for ψ, the radius R_i of the arm must be expressed in centimeters, the frequency ν in cps), θ is the angle between the directions of the magnetic field and of the visual ray. At isotropic distribution of relativistic electron velocities the intensity of the polarized component is proportional to

$$p(H\sin\theta)^{\frac{\gamma+1}{2}}R_p/\sin\theta. \qquad (2)$$

Substituting the expression for p in this formula, and effecting the integration over the solid angle, we shall obtain a quantity proportional to the intensity of the polarized emission arriving from the given solid angle. We determined by way of numerical integration the fraction α of polarized radiation for a series of values of parameters, in a band of 50° width with a central cross section perpendicular to the axis of the arm. If R_p exceeds significantly R_i, we shall have $\alpha < 90\%$ for any gas concentration (so long as depolarization is not manifest, because of finite width of antenna radiation pattern). For example, at $R_p = 2R_i$ and $\gamma = 3$*, the quantity α does not exceed 65%. The values $\alpha \sim 90\%$ are possible only at $R_p \simeq R_i$. In this case we obtain from formula (1) the well known expression [12]

$$p \backsim |\sin(\psi\operatorname{ctg}\theta)/\psi\operatorname{ctg}\theta|. \qquad (3)$$

The quantity α depends feebly on the concentration of gas. Thus, at $R_p = R_i = 250\,\text{nc} = 7.5\cdot 10^{20}$ [8, 9], $\gamma = 3$, $H = 10^{-5}$ oe, $\nu = 408$ Mc/s, $\alpha = 94.5\%$, provided $N = 0.1\,\text{cm}^{-3}$ and $\alpha = 87.6\%$ if $N = 0.01\,\text{cm}^{-3}$. However, for the estimate of N we may also take advantage of the fact that the intensity of polarized radiation and the position angle vary little at moving away from the center of the band by $\pm 15^{\circ}$. As may be seen from formulas (2) and (3), this is possible for $\psi \operatorname{ctg} 75^{\circ} \lesssim 1$. Hence it follows that $\psi \lesssim 3.7$ rad; in the frequency $\nu = 408$ Mc this corresponds to values $NHR_i \lesssim 2.6 \cdot 10^{13}$ oe cm^{-2}. Assuming $R_i = 250$ nc and $H = 10^{-5}$ oe, we shall obtain $N \lesssim 3.5 \cdot 10^{-3}$. At the same time $\alpha = 84^{\circ}$.

Let us consider now the second model: all the ionized gas is concentrated in dense clouds. We shall estimate that the emission of regions situated beyond the clouds are depolarized on account of the Faraday rotation in the clouds [10]. In order to find the quantity α, we must determine the average distance to the first cloud over the visual ray $\overline{R}$. Resolving the problem analogously to what is done when finding the mean length of the free part of molecules in a gas, we obtain the expression

$$\overline{R} = a\left[1 - \exp\left(-\frac{R_p}{a \sin \theta}\right)\right], \tag{4}$$

where $a = 1/\sigma n$, σ is the mean area of cloud projection on the plane perpendicular to the visual ray, n is the number of clouds in a unit of volume. According to (4), in the case $a \gg \frac{R_p}{\sin \theta}$, the mean distance is $\overline{R} \sim \frac{R_p}{\sin \theta}$. At the same time, $\alpha(\gamma = 3) = 52.5\%$ (as in model 1 in the absence of Faraday rotation). The maximum value $\alpha(\gamma = 3) = 59.4\%$ is obtained at $a \ll R_p (\overline{R} \sim a)$. and at $a \sim R_p$, $\alpha(\gamma = 3) = 56.4\%$. Therefore, basing ourselves upon the second model, we cannot obtain a value of α agreeing with the experimental data, provided, of course, we do not assume notable anisotropy in the distribution of the direction of velocities of relativistic electrons, for which there is no foundation.

From the above considerations the following conclusions are derived:

1) Observations of polarization of cosmic radio emission do not corroborate the assumption of existence near the galactic plane of an ionized gas layer with concentration ~ 0.1 cm^{-3} and half-thickness ~ 300 nc.

2) Neither of the two considered models of ionized gas distribution in the galactic arm authorizes us to explain all the characteristic peculiarities of the angular distribution of the polarized radio emission in 408 Mc. But this can be done by combining the two models. Thus, the true distribution of ionized gas must be characterized by the cloud structure with gas concentration between clouds $N \lesssim 3.5 \cdot 10^{-3}$ cm^{-3}; at the same time the clouds

must not fully depolarize the emission of frequency 408 Mc traversing them. These representations are corroborated by [13] and by estimates of Faraday rotation in the interstellar medium by the data of polarization measurements in the frequencies of 408 and 616 Mc/s [14].

3) The available polarization data do not contradict the assumption of isotropic distribution of velocity directions of cosmic electrons in the interstellar space.

4) The absorption of longwave cosmic radioemission is apparently conditioned by clouds of ionized gas.

THE END

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